

Towards information-centric WSN simulations

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ABSTRACT

In pursuance of integrating Wireless Sensor Networks (WSNs) with other systems, the use of techniques from other fields, such as machine learning and information processing, are becoming more common. Therefore, we faced the problem of missing network simulations that are not only focused on the packet exchange between network elements, but also in the data that is transmitted between them. In other words, we needed a tool that evaluated the WSNs on how they evolve and react to the environmental changes. To illustrate the benefits of having such perspective, we explain the kind of simulation problems that we solved in our last work. Moreover, we outline the next steps in the direction of creating an extension to support this approach.

Keywords

OMNeT++, simulation, wireless sensor networks, information processing

1. INTRODUCTION

The use of Wireless Sensor Networks (WSNs) on different types of environments has become common in the past years. As a consequence of this, monitoring systems that were composed only by wireless sensor nodes evolved and are now capable of using data from multiple sources of data to produce knowledge (which we will refer to as *information*). In order to better utilize this information and be able to react to environmental changes, machine learning and information processing techniques started to be incorporated to these systems. Therefore, the models that mainly focused on the dynamics of network protocols and elements, now may also consider the information that they produce and how it is handled. Incorporating the support to the information processing in a simulator makes it possible to reproduce the information flow and the information processing, as well as the effect that such information may have on the network dynamics. This is specially relevant, considering that simulations are an important tool on a model validation task.

At the current state, OMNeT++ [1] does not focus on these features. In order to support the information processing and to simulate the decision making process, the simulations should be extended to use the networks as modules in their structure. With that, they would be able to run, in parallel, multiple WSNs that can operate completely independent of each other or exchange the knowledge produced by their sensor nodes and produce a richer knowledge about the environment. In the end, the simulations could have

algorithms to increase the WSNs lifetime, as well as their accuracy, their reliability and, consequently, the relevance of the information produced.

The remainder of this paper is structured as follows. In Section 2, we describe the need for information-centric simulations and illustrate it with an example of a system that intelligently uses data from external WSNs to improve the operation of its own WSN. Section 3 shows how we handled this problem and ran simulations using WSNs that exchanged information. Finally, Section 4 outlines the next steps in the direction of having a concrete solution for such kind of problem.

2. PROBLEM STATEMENT

As a natural evolution, monitoring systems that were primarily composed only by WSNs, now tend to be improved with self-manage capabilities, which turns it possible to update their behavior according to the data produced by their elements. As part of this process, data from external WSNs can be used to reduce the energy consumption and improve the quality of the measurements done by internal WSNs, called as inter-WSNs information exchange [2, 3]. The main idea behind this concept is that the data gathered by other WSNs can be exchanged via their gateways and used to infer and/or predict values that are not available locally. Based on this inference, the systems are able to improve the operation of their wireless sensor nodes without losing the quality of the information obtained by the gateway.

For example, based on the information received from external systems, it may be possible to infer the data that was going to be measured by a specific node and calculate what is the uncertainty level of those predictions according to correlated measurements [4]. In case of a low uncertainty level, the node's operation can be updated by the gateway in order to save energy and increase its lifetime, as there is no need to make the measurement. Otherwise, the gateway can actively query some missing data or update the WSN's operation by deactivating nodes or changing the time between two measurements.

Although it may sound a simple and straight solution, there are two main aspects to be observed before applying these updates: the current environmental state, which may not allow a node to be turned off, for example; and the costs (e.g., the energy consumption in the nodes) to disseminate the updates to the nodes, which can vary depending on the current WSN state and its topology. These decisions, may have a relevant impact in the WSN evolution in time.

If the simulations focus on the information exchanged by

the nodes rather than on the packet transmissions, it is possible to model more accurate scenarios involving WSNs and the environmental changes around them. Hence, for instance, we can consider the interaction between multiple WSNs in runtime. To simulate such a scenario, it is required a way to evaluate the quality of the measurements done by the sensors and the WSNs performance, which usually depends on the quality of the information received from other WSNs and may vary depending on how they reacted to the last environmental changes.

The current workaround for this kind of problem is to split the simulation into many parts. For example, the results about the energy consumption obtained in OMNeT++ are used as input in Matlab and, after processing the information and making decisions in Matlab, new OMNeT++ simulations are run to apply the reactions. Besides the high overhead to run the simulations in sequence, the transition from one platform to the other may result in missing information about the system's state, given that a new simulation may not contain all the information about the environment at the end of the last one.

3. CONTRIBUTION

In [5], we used OMNeT++, INET and MiXiM to simulate an architecture for exchanging information between external WSNs. For those simulations, we developed a special type of gateway. It is directly connected to their respective WSN sink nodes, as well as maintain an overlay connection with the other gateways in order to exchange information about their networks and measured data. Thus, the gateways run an algorithm that infers values based on the information that is available for them at runtime. Based on the output of this algorithm, they make decisions about changing the operation of the nodes and producing more or less measurements.

Apart from developing the algorithm that handles the data in INET, we did small changes in MiXiM to use the WSNs as modules in our simulations. With that change in perspective, different types of WSNs can run in parallel and exchange the information produced by their nodes in real time. The difference from typical simulations is that, in this case, the system evolves in time according to the data that is transmitted by the wireless sensor nodes. Thus, the data that is produced by the algorithm that infers and/or predicts the measurements affect the network topology in the next time-interval, which reflects in the further decisions in a cascade effect. As usual, the simulation is able to report the required time to query data from specific nodes and to transmit them through the network, as well as the energy consumption. Based on these values, the algorithm used in the gateway may adapt, change or update its parameters to react to the environmental changes and work at the optimal operating level.

4. FUTURE WORK

In OMNeT++, there are many tools to save the statistics and plot data about the wireless sensor nodes, but usually the modules that handle the information generated by a WSN are developed in other platforms, such as Matlab¹ and R², or in different languages other than C++. Also, some of

them are part of a commercial software or make use of third-part APIs. There is a missing gap between OMNeT++ and those external sources, and standard solution for this problem would facilitate the information-centric simulations.

Based on the fact that Matlab includes tools that are useful for machine learning and information processing, the next steps to have a information-centric extension include creating a way to communicate with other platforms to process the information produced by the networks during the simulation runtime. With these changes, it would be also possible to use the simulation results to make decisions in real time systems.

5. ACKNOWLEDGMENTS

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¹<http://www.mathworks.es/products/matlab/>

²<http://www.r-project.org/>